

Cystopteris, *Lindsaya*, and the *Pteridæ*. But this sequence is already laid out in this order in the Synopsis, and it illustrates one at least of the lines along which mixed forms are believed to have been derived from the *Gradatæ*. No attempt has been made to follow the natural grouping of the *Mixtæ* into detail, or to test the arrangement of them in the Synopsis. Sufficient has, however, been said to show that the systematic divisions of the ferns now proposed fall in readily with the system of Sir William Hooker, notwithstanding that they are based upon details of which he cannot have been aware.

“Note on the Fertility of different Breeds of Sheep, with Remarks on the Prevalence of Abortion and Barrenness therein.” By WALTER HEAPE, M.A., Trinity College, Cambridge. Communicated by W. F. R. WELDON, F.R.S. Received March 9,—Read April 20, 1899.

The importance of fertility as a factor in the survival of a species is admirably demonstrated by Haffkine,* whilst Professor Karl Pearson† shows that fertility when correlated with other characteristics works a progressive change, and that not only is fertility a race characteristic, but may be a class characteristic in the human species.

Among domesticated animals, although fertility may be a racial characteristic, its importance may be much reduced from a variety of circumstances.

Among sheep there is undoubted evidence of the racial character of fertility, but the quality of the wool or the value of fat sheep of a particular breed may render that breed worth keeping in spite of a low rate of fertility as compared with other breeds. Then the rate of fertility may be artificially increased, as when certain rams of undoubted value as progenitors, but useless as breeders if left to themselves, become valuable sires by the help of the shepherd. In the same way a certain breed of sheep, kept in one district and managed in a particular manner, may be more liable to abortion, or to barrenness, or to mortality among the lambs, than the same breed in another district managed in another way, and yet the former may, on account of the supply of food which it is possible to grow there per acre, prove the most remunerative.

From these and many other similar reasons the survival of a particular breed or its retention in, or importation to, a particular district is not necessarily due to natural fitness or adaptability. At the same time a

* “Recherches sur l'adaptation au milieu chez les Infusoires et les Bactéries; contribution à l'étude de l'immunité,” ‘*Annales de l'Institut Pasteur*,’ vol. 4, 1890.

† “Contributions to the Mathematical Theory of Evolution. Note on Reproductive Selection,” ‘*Roy. Soc. Proc.*,’ vol. 59, 1896.

wider knowledge of the racial character of fertility among sheep might exercise considerable influence on the survival of certain breeds in the future. Just as the number of Long-horn cattle is rapidly becoming reduced in this country on account of the length of time they require to come to maturity and fatten, so the low fertility of Southdowns if it cannot be increased may lead to the retention of that breed in the hands of only a few special breeders.

The following account is a brief abstract of information obtained from 397 sheep breeders who have supplied me with records of flocks containing 122,673 ewes for the breeding season of 1896-97. Table IV records certain particulars of eight pure breeds separately, and of ten pure breeds jointly ("Various Pure Breeds"; details of only a small number of flocks were supplied for each of these ten breeds). These are totalled, particulars of fifty-nine flocks of various cross-bred sheep subjoined, and the totals for all breeds finally arrived at.

Besides the figures contained in Table IV, other statistics were supplied regarding the age of rams and ewes, the size of breeding flocks, the proportions of rams and ewes therein, the usual and the highest percentages of barrenness experienced, &c. To this were added remarks on the food given to rams and ewes at specified times, on their condition during the breeding season, on various methods of management of breeding flocks, and on numerous views regarding matters which are supposed to influence fertility, abortion, and barrenness amongst ewes; finally particulars of districts, subsoils, and weather were noted, and the subject considered statistically from all these various points of view for each breed.

The variation in the numbers of flocks and of ewes concerned in the various calculations for each breed (see Table IV) is due to the inability of all flock-masters to supply the whole of the information asked for in the schedule, which, by the kindness of the Royal Agricultural Society, was distributed to them, and is not due to my selection of flocks.

Fertility.

It is to be noted the number of lambs returned does not always represent the number born; that information, although asked for, was not always forthcoming and sometimes the number of lambs alive when the schedule was filled up was given instead. The percentage of twins given is, however, a check on this element of error, and in the following account the columns under "lambs" and "twins," Table IV, are considered together. The error is most apparent in the Hampshire Down, Oxford Down, Dorset Horn and Lincoln breeds; in the other four breeds, in which the records have been most carefully kept, the Suffolk, Shropshire, Kent and Southdown breeds, their fertility is demonstrated to be a racial character.

The Suffolk breed is by far the most fertile, while the Southdowns are at the bottom of the list: the value of the former as a prolific breed is incontrovertible, while the record of the latter, as shown both by the percentage of twins and lambs, is so low as to suggest cause for some anxiety and to show urgent need for close attention on the part of breeders.

The Hampshire breed also stands low both with regard to twins and lambs, especially when its low percentage of loss from abortion and barrenness is considered; whereas the Lincoln breed, although recording only 111.1 per cent. of lambs, shows 29.09 per cent. of ewes bearing twins, and the fault, with this breed, is obviously not so much low fertility as heavy mortality among lambs and a high percentage of loss from abortion and barrenness.

The most fertile of all pure breeds of which I have records, is the Wensleydale breed, in which six flocks with a total of 319 ewes produce 177.43 per cent. of lambs (included in "Various Pure Breeds"). It is to be noted that both Wensleydale and Suffolk ewes when covered by rams of other breeds, do not appear to produce a larger percentage of lambs than they produce when covered by rams of their own breed; if anything, they seem to produce a somewhat smaller percentage of lambs. On the other hand, Dorset Horn ewes are more usually fertile and are more prolific with Down rams than with Dorset Horn rams.

It is a very usual practice with Dorset Horn flock-masters to keep a Down ram to cover those ewes which fail to become pregnant to a Dorset Horn ram, and, when pure-bred ewes are discarded from their breeding flocks, they generally sell them "in young" to Down rams, when they frequently produce as many as 170 per cent. of lambs.

It appears, therefore, that whereas the fertility of Suffolk and Wensleydale ewes is at its maximum when they breed to rams of their own kind, Dorset Horn ewes require to be covered by rams of another breed, in order that they may be stimulated to the greatest generative activity.

Apart from the percentage of ewes which abort or are barren from accident or constitutional defects, the fertility of ewes is chiefly affected by their condition and by the condition of the ram at tupping time. I have overwhelming evidence that flocks in strong condition at tupping time produce a higher percentage of lambs than flocks in poor condition at that period (Suffolk, Kent, Hampshire, Dorset Horn, and Lincoln breeds); on the other hand, fat rams and ewes are associated with a high percentage of barrenness, and not with a high percentage of lambs.

In close connection with this subject is the production of twins. Fifty-five per cent. of the flock-masters who send information on this head, report that twins are usually born early in the lambing season, and many of them add that otherwise the crop of lambs is small. That

is to say, that most twins are produced by the ewes which first come in season, and I interpret that to mean that it is the ewes with the most active and most vigorous generative system, those which are in strong breeding condition at that time, which bear the most twins. It is of interest to note that among Southdown and Hampshire flocks, a comparatively small proportion of twins are born early in the lambing season, and these breeds produce the smallest percentage of twins.

The effect of locality upon the fertility of a breed is worthy of consideration, and statistics are given in Table V to illustrate this point.* In considering these figures, numerous other important influences must be borne in mind, which the information at my disposal makes it impossible to dissociate from locality ; and in all cases, except those of the Shropshire and Lincoln breeds, where a wide difference in fertility is shown in different districts, it is possible that the variation in fertility may be due to one or other or all of these various influences, apart altogether from locality.

The fertility of a flock is greatly influenced by its management and by the conditions under which it lives ; the condition, kind, and amount of food available before tupping time will affect the condition of the ewes and the percentage of twins subsequently born ; the season may be more favourable for tupping or for lambing in one district than in another ; cold, rain, or want of rain, will affect the feed, the ground, and the ewes themselves ; while, owing to mortality among ewes during lambing or at other times in the preceding year, the flocks in one district may consist of a larger proportion of shearling ewes than the flocks in another district, and this may affect the birth rate of a flock.

These and numerous other such influences, combined with the undue proportionate value of excessive loss or fertility in one flock, where only a few are kept in a district, is sufficient to account for a much greater variation than is shown for most breeds in Table V. At the same time the difference in fertility of Shropshire flocks kept in Staffordshire, as compared with other flocks of the same breed kept elsewhere, and of Lincoln flocks kept in Yorkshire, as compared with those kept in the home county, is very remarkable. They certainly suggest that Yorkshire is a more satisfactory habitat for the Lincoln breed than is the home county, and although it is quite possible the method of farming and other influences, in Lincolnshire, are responsible for some of the difference, they can hardly be responsible for all of it. I do not believe that the high percentage of loss in the Lincolnshire wold flocks is due altogether to mismanagement, but if 50 per cent. of the difference between the losses of the wold flocks and the Yorkshire flocks was added to the percentage of twins of the former, there would still be a difference of 17 per cent. of twins in favour of the Yorkshire

* See "Percentage of Twins."

flocks. So also with the Shropshire breed in Staffordshire and the home county, if 50 per cent. of the difference between the losses was added to the percentage of twins in the home county, they would still have 12 per cent. less than the Staffordshire flocks; and it is not probable that a different method of farming in these two neighbouring districts can account for such difference in fertility.

The returns of the Suffolk flocks in Essex are misleading, inasmuch as some of the flocks with the highest percentage of lambs do not show the percentage of twins; at the same time I am disposed to think that Essex is not so favourable a county as Suffolk for this breed of sheep.

The difference in the return of lambs for Southdowns in East Anglia and in the South, is probably due to the more careful records which the smaller size of the flocks and the method of farming in East Anglia allows, and I suspect the difference in the percentage of twins may be similarly accounted for.

In neither of the cases where different breeds are represented in the same locality, does the percentage of twins of the foreign flocks approach that of the home breed. Southdowns do not approach the fertility of Suffolks in East Anglia, nor do Hampshires become as fertile as Dorset Horns in the West country.

The Suffolks, Hampshires, and Dorset Horns are most fertile in their home districts; in the case of the Shropshire breed, Staffordshire may be considered a part of the home district; and only in the case of the Lincolns is it demonstrated that any breed thrives better in a foreign district than at home. This was to be expected, for it can hardly be doubted that natural selection, as well as artificial selection, has been at work on the different breeds of sheep in this country.

In the case of the Lincoln breed it is of interest to note, in this connection, that the method of farming in some parts of Lincolnshire has greatly altered in modern times; for instance, the facility which the soil on the wolds affords to grow especially fine crops of roots, enables the flock-masters in that district to keep more sheep per acre than is possible on the low-lying farms; this leads to crowding and to other even more artificial conditions which, as the statistics indicate, are not favourable to the fertility of the breed; on the other hand several of the more successful flocks in Yorkshire are run on grass chiefly and under more natural conditions for sheep.

The variation in fertility in different districts does not, however, affect the racial character of the fertility of the different breeds (compare Tables IV and V—"Per cent. of Twins"), except in the case of the Lincolns, where the returns of the Yorkshire flocks suggest that this breed should be placed in the first rank with the Suffolks and Shropshires, instead of in the second rank with Dorset Horns, Oxford Downs, and Kents. The position of the Southdowns at the bottom of the list remains unaltered.

While the percentage of lambs and of twins in cross-bred flocks is greater than the same percentage for the total pure-bred flocks, the ewes of certain pure breeds are undoubtedly more fertile than the average cross-bred ewe.

The flock percentage of lambs in 306 pure-bred flocks, ranges from 203·8 to 59·09 per cent., the percentage for 89,370 ewes being 120·4 per cent. The most frequent percentage in these 306 flocks is between 110 and 120 per cent.; the following Table (I) shows this, and as the column for "under 110 per cent." includes all failures, the excess in the 110 per cent. column is all the more marked.

There are more flocks of between 100 and 200 ewes than of any other number, and it is in these flocks the highest percentage of lambs occur; broadly speaking, the frequency of a high percentage of lambs, and the height of that percentage, vary in proportion to the number of flocks and to their size.

Abortion and Barrenness.

There is an element of error in these statistics, due to the fact that some ewes abort at an early stage of gestation, when the foetus is small and the circumstance liable to be overlooked by the shepherd; some of these ewes come "in use" again and are again served by the ram, but some do not again come "in use," or, owing to the fact that they have already been drafted into a flock without a ram, they are not again covered; in either of these cases they are put down as barren. Thus, although I do not believe the error is a great one, the percentage of abortion in ewes may be higher and the percentage of barrenness lower than is represented in Table IV.

The total loss from both these causes amounts to 7·1 per cent. for all pure-bred ewes; of these the Lincoln sheep suffer the most (12 per cent.) and the Hampshires the least (4·01 per cent.), a very startling difference and of specially grave significance to Lincolnshire flockmasters on the wolds (see Table V).

Abortion.

In 300 pure-bred flocks the percentage of abortion varies from 23·75 per cent. to 0, while the percentage for 85,878 ewes is 2·39. The Dorset Horn (4·11 per cent.) and the Lincoln (4 per cent.) breeds suffer most, while all other breeds except Southdowns have less than 2 per cent. The causes which induce a high percentage of abortion are little understood, and severe losses are from time to time experienced from no known cause (Lincolns 20 to 30 per cent. and Dorset Horns).

Statistics supplied indicate, that an undue proportion of shearling

Table I.—Total Pure-bred Flocks. Lambs—per 100 ewes.

Flocks of	Under 110 p.c.	110 p.c.	120 p.c.	130 p.c.	140 p.c.	150 p.c.	160 p.c.	170 p.c.	180 p.c.	190 p.c.	200 p.c. and over.	Totals.
Under 100	1	7	10	6	8	6	7	4	1	1	..	51
100—199	7	17	11	4	10	12	8	2	2	1	1	85
200—299	9	16	12	6	10	8	..	1	..	..	..	62
300—399	13	12	7	3	4	1	..	..	..	..	..	40
400—499	9	9	3	4	2	..	..	..	..	..	..	27
500—599	1	3	5	1	..	..	..	..	..	..	..	10
600—699	3	1	2	2	..	..	..	..	..	..	..	8
700—799	3	1	..	2	..	..	..	..	..	..	..	6
800—899	3	..	1	1	..	..	..	..	..	..	..	5
900—999 .....	..	..	1	..	..	..	..	..	..	..	..	1
1000 and over	4	3	3	1	..	..	..	..	..	..	..	11
Total	53	69	55	40	34	27	15	7	3	2	1	306

ewes in a flock is associated with a high percentage of abortion (Lincolns), and that ewes of a particular breed run on certain subsoils or in certain districts are more liable to abortion than the average for that breed, as, for instance, Lincolns run on the wolds and Hampshires on oolite formation.

In some parts of Lincolnshire abortion sometimes approaches, if it does not actually assume, an epidemic form; at such times several neighbouring flocks may experience between 30 and 40 per cent. of aborted ewes; I am unaware of a similar form of abortion in any other district.

Unsuitable food, causing indigestion and intestinal irritation, and poor food, resulting in poor nutrition, are probably responsible for the greatest proportion of abortion in ewes. It is not the kind of food, as is frequently supposed, but the condition of that food which is at fault, and, as a result, my schedules show that poor condition of ewes during gestation is undoubtedly associated with a relatively high percentage of abortion.

The highly artificial conditions under which sheep are kept in many districts in this country, renders the question of the most suitable food for breeding ewes a very important question, and it is one regarding which but little attention has been paid.

The most frequent percentage of abortion experienced in 300 pure-bred flocks is shown in Table II to be under 1 per cent. The highest percentage is relatively more frequent in large than in small flocks, and this table shows that much more irregularity is experienced in abortion than Table I shows is the case for fertility.

Barrenness.

In 327 flocks of pure-bred ewes the percentage of barrenness varies from 51.42 per cent. to 0, while the percentage for 96,520 ewes is 4.71. The Lincoln (8 per cent.) and the Shropshire (6.06 per cent.) breeds suffer the most, while, with the exception of Hampshire Downs, Dorset Horns, and Suffolks, no pure breeds record less than 5 per cent. loss from this cause.

The district or subsoil on which ewes are run is associated, in certain breeds, with the proportion of barrenness experienced: thus, Lincoln sheep run on the wolds, Shropshire sheep on new red sandstone subsoil, and Hampshire sheep elsewhere than on chalk downs, are associated statistically with a relatively high percentage of barrenness; an excessive proportion of shearling ewes in a flock is also frequently found associated with a high percentage of barrenness; but the quality of the food given and the condition of the rams and ewes at tupping time is no doubt the chief factor which influences the barrenness percentage.

Fat is well described as an enemy to fruitfulness, while the want of

Table II.—Total Pure-bred Flocks.—Abortion.

Flocks of	Under 1 p. c.	1 p. c.	2 p. c.	3 p. c.	4 p. c.	5 p. c.	6 p. c.	7 p. c.	8 p. c.	9 p. c.	10 p. c. and over.	Total.
Under 100	14	14	6	3	3	2	2	1	..	..	..	45
100—199	45	20	12	5	1	..	2	1	..	..	2	88
200—299	31	17	8	1	4	1	..	..	..	1	1	64
300—399	20	11	4	..	1	1	1	1	..	1	..	40
400—499	9	7	5	2	1	..	..	..	..	..	2	26
500—599	5	..	1	..	..	..	..	..	..	..	..	6
600—699	4	4	..	1	..	..	..	..	..	..	2	11
700—799	2	1	..	1	..	..	..	..	..	..	1	5
800—899	2	..	..	..	..	..	..	..	..	..	2	4
900—999 .....	..	..	..	..	..	..	..	..	..	..	..	..
1000 and over	2	4	3	1	..	..	..	..	..	..	1	11
Total	134	78	39	14	10	4	5	3	..	2	11	300

Table III.—Total Pure-bred Flocks.—Barrenness.

Ewes in flocks of	Under 1 p. c.	1 p. c.	2 p. c.	3 p. c.	4 p. c.	5 p. c.	6 p. c.	7 p. c.	8 p. c.	9 p. c.	10 p. c. and over.	Totals.
Under 100	16	11	3	5	3	5	3	..	1	1	3	51
100—199	16	21	12	8	3	9	5	4	5	1	11	95
200—299	6	11	13	8	5	7	4	3	2	1	6	66
300—399	9	6	7	2	5	1	..	2	2	..	7	41
400—499	6	7	..	3	2	3	2	.	1	1	3	28
500—599	1	2	1	1	..	3	..	1	..	1	..	10
600—699	1	1	1	4	2	2	..	..	..	..	..	11
700—799	1	..	1	..	..	2	1	1	..	..	..	6
800—899 .....	..	..	..	2	..	1	1	..	..	1	1	6
900—999 .....	..	..	..	..	..	1	..	..	..	..	..	1
1000 and over	3	2	1	..	..	3	..	2	1	..	..	12
Total	59	61	39	33	20	37	16	13	12	6	31	327

Table IV.

Breed.	No. of flocks.	No. of rams.	No. of ewes.	Lambs.				Twins.				Abortion.				Barrenness.				Total loss aborted and barren.
				No. of flocks.	No. of ewes.	No. of lambs.	Lambs per 100 ewes.	No. of flocks.	No. of ewes.	No. of ewes bearing twins.	Per cent. twins.	No. of flocks.	No. of ewes.	No. of aborted ewes.	Per cent. aborted.	No. of flocks.	No. of ewes.	No. of barren ewes.	Per cent. barren.	
1. Suffolk	38	161	7,506	36	7,170	10,165	141.77	16	2,453	1,490	52.22	36	6,861	92	1.34	36	7,130	231	3.28	4.62
2. Kent	15	254	9,931	13	8,481	10,521	124.05	11	6,703	2,104	31.38	9	3,901	54	1.33	15	9,931	549	5.52	6.50
3. Southdown ...	23	186	9,134	22	7,834	8,604	109.89	18	6,583	1,229	18.67	21	8,894	255	2.86	23	9,134	464	5.08	7.94
4. Hampshire ...	53	473	26,400	50	21,860	28,512	114.69	41	21,141	5,093	24.09	48	23,755	371	1.56	51	25,100	615	2.45	4.01
5. Oxford Down	20	83	3,555	18	3,189	3,800	119.16	14	2,661	911	35.02	16	2,688	36	1.34	20	3,555	180	5.06	6.40
6. Dorset Horn...	31	170	10,275	25	8,163	10,092	123.63	27	8,588	3,225	37.55	23	9,020	371	4.11	29	9,408	273	2.9	7.01
7. Shropshire ...	60	196	8,492	56	8,044	11,004	136.79	36	4,121	1,832	46.24	52	7,428	112	1.50	58	7,882	478	6.06	7.56
8. Lincoln	62	387	17,880	54	15,789	17,542	111.10	46	11,430	3,226	29.09	59	16,697	668	4	60	16,570	1,325	8	12
9 to 18. Various pure breeds	36	195	10,010	32	5,840	7,338	126	25	4,513	1,268	28.09	31	6,636	93	1.4	35	7,810	436	5.58	6.98
Total pure breeds	333	2,085	103,193	306	89,370	107,603	120.40	237	68,535	20,578	30.02	300	85,878	2,052	2.39	327	96,520	4,554	4.71	7.10
19. Cross-breeds...	59	415	19,480	52	12,165	15,751	129.47	33	9,314	2,891	31.04	50	11,361	173	1.52	57	18,060	589	3.25	4.77
Total all breeds...	397	2,500	122,673	358	101,535	123,354	121.48	275	77,850	23,469	30.14	350	97,239	2,225	2.38	384	114,580	5,142	4.48	6.76

Table V.

Breed.	Locality.	Number of flocks.	Number of ewes.	Per cent. of lambs.	Per cent. of twins.	Per cent. of loss, abortion, and barrenness.	Remarks.
Suffolks	Suffolk..... Essex.....	28 8	5,493 1,458	141·16 146·16	60·46 42·87	4·5 5·21	Some of flocks with highest per cent. of lambs did not return per cent. of twins.
Southdowns ...	South (Hants, Surrey, Sussex) .. East Anglia (Norfolk, Suffolk, Essex, Cambridgeshire)	13 6	6,278 1,745	109·51 119·02	19·71 22·62	7·42 7·17	Small flocks.
Hampshires	South (Hants) West (Dorset, Wilts, Somerset) ..	15 27	5,465 18,621	108·73 116·3	27·85 22·4	4·2 3·7	
Dorset Horns ..	West (Dorset) Isle of Wight.....	19 4	6,580 1,497	122·46 130·67	38·49 36·07	6·88 12·7	One flock had excessive barrenness.
Shropshires	Shropshire.....	22	2,998	134·2	40·8	10·43	Exceptionally heavy losses from barrenness.
	Staffordshire..... Herefordshire	9 9	1,265 1,039	154·15 133·51	54·97 33·09	6·08 5·29	
	Lincoln (Wolds)	16	6,843	101·33	23·75	17·78	Heavy losses from both abortion and barrenness.
Lincolns	" (elsewhere) Yorkshire	29 9	8,091 1,629	115·58 127·26	24·13 47·57	7·79 4·78	

Note.—The Kent flocks are all run in Kent. The Oxford Down flocks, in my records, are so scattered, that a sufficient number of flocks for the purpose of comparison is not to be found in any two districts.

sufficiently nutritious food also results in poor returns of lambs. Among Suffolk and Shropshire ewes, which are highly fed as a rule, a high percentage of barrenness occurs in cases where they are excessively highly fed; on the other hand, among Dorset Horn, Lincoln, and Kent ewes, which are certainly not too highly fed as a rule at tupping time, the highest percentage of barrenness occurs among the poorest kept flocks.

The most frequent percentage of barrenness experienced in 327 flocks is 1 to 2 per cent., but, as Table III shows, the returns are much more irregular than was the case for abortion, and there is a much larger proportion of flocks in the "10 per cent. and over" column. The slightly excessive proportion of flocks in the 5 per cent. column suggests generalised results rather than accurate returns, but the number of flock-masters who are responsible for this is obviously very small.

In conclusion:—

1. Whereas the total loss from abortion and barrenness is fairly constant for most pure breeds of sheep, the Suffolks and Hampshires are markedly free from, and the Lincolns markedly liable to, heavy loss from these causes.

2. Although the loss from the above causes does exert an influence on the returns of fertility of the various breeds, it does not account for the wide variation which exists in this respect.

3. The ewes of certain pure breeds are conspicuously more fertile than the average cross-bred ewe; and

4. The fertility of certain pure breeds is sufficiently marked to constitute a racial characteristic.

"Some further Remarks on Red-water or Texas Fever." By ALEXANDER EDINGTON, M.B., F.R.S.E., Director of the Bacteriological Institute, Cape Colony. Communicated by Dr. D. GILL, C.B., F.R.S. Received March 13,—Read April 20, 1899.

Since my communication* to the Royal Society of London, by Professor Thomas R. Frazer, I have been able to obtain valuable addi-

* The conclusions arrived at in that communication (received June 6, 1898) were as follows:—

1. The blood of animals, themselves healthy, from a red-water area is dangerous if inoculated into an animal which suffers coincidentally from another disease.

2. That the blood of animals suffering from mild or modified red-water may be safely used to inoculate a healthy animal *subcutaneously*, but is dangerous when injected into a vein.

3. That the subcutaneous inoculation of mild or modified red-water blood conveys a mild form of the disease, and since the blood of such an animal is viru-